COATINGS. ENAMELS

UDC 666.293.666-416:697.27

FILM HEATERS WITH CURRENT-CONDUCTING COATINGS BASED ON PHOSPHATE BINDERS

E. V. Shinkareva[1] and V. V. Tavgen'[1]

Translated from Steklo i Keramika, No. 5, pp. 31 – 32, May, 2002.

Current-conducting coatings formed on enameled steel substrates at low temperatures (560 – 580°C) with good service characteristics are developed. Household and industrial heaters can be developed on the basis of such coatings.

Tubular electric heaters with heating elements in the form of a nichrome spiral are currently used for low-temperature heating (up to 300°C) in engineering and household equipment. However, due to the low thermal conductance of electric insulation, the heating elements become overheated, which impedes the formation of a uniform thermal field.

Film heating elements that represent a conducting coating formed on an enameled steel substrate can be competitive in the low-temperature range and make it possible to design simpler and more reliable heaters, both for household and for industrial use.

The purpose of the present study is to develop film heating elements based on current-conducting composite coatings and to determine their service parameters.

The initial materials for producing conducting coatings were an aluminochromium-phosphate binder with the molar ratio of $P_2O_5 : (Al_2O_3 + Cr_2O_3) = 2.3 – 3.2$, density $(1.60 – 1.75) \times 10^3$ kg/m^3, and pH = 0.93 (TU 6-18-166–83), calcium-hydride-titanium PTOM (TU 14-1-3086–80) and reduced chromium PKhM (TU 14-1-1474–75, USSR Inventor's Certif. No. 1492990). The estimated quantities of the filler, the binder, the suspending additives, and waster were mixed in a porcelain drum. The resulting slip of the conducting composite was deposited on enameled plates (150 × 250 mm) and electric radiator panels (468 × 496 mm) by spraying.

The surface of the samples intended for application of the conducting coating was enameled with one undercoat layer and two layers of cover insulating enamel 12p (USSR Inventor's Certif. No. 1447762).

[1] Institute of General and Inorganic Chemistry of the National Academy of Sciences of Belarus, Minsk, Belarus.

The experiment demonstrated that the slip is stable in storage, allows complete control of the flow properties by varying the quantities of water introduced, and has a pH equal to 1.93. For spray deposition of coatings, the slip density should be within the limits of 2.63 – 2.81 g/cm^3, and the covering capacity should be 5.8 – 7.9 g/dm^2. The thickness of the deposited layer is equal to 100 – 150 μm. The heat treatment of articles was performed at a temperature of 500 – 580°C for 10 min. The electrodes were deposited by spraying copper using an ÉM-14M metal spray gun.

Testing carried out at the Électromodule JSC (Molodechno) confirmed the good reproducibility of the electric resistance (i.e., the prescribed resistance interval was met). The reproducibility of coatings heat-treated at 500 – 580°C for 10 min can be estimated from the data in Table 1.

It can be seen that coatings heat-treated at 560 – 580°C have better reproducibility of resistance since within this interval the resistance of a coating insignificantly depends on the treatment temperature and has close values in spite of the temperature differences inside the furnace.

TABLE 1

Treatment temperature, °C	Resistance* of samples, Ohm			Maximum deviations in resistance, %
	minimum	maximum	average	
500	231.2	421.2	323.7	+ 30.1 – 28.6
560	99.8	127.8	113.5	+ 12.6 – 12.9
580	103.9	126.9	114.6	+ 9.6 – 9.4

* Calculation performed on 8 samples.

0361-7610/02/0506-0180$27.00

It is established that the maximum temperature and the heating rate of the heater elements are determined by their power, the substrate thickness, and the heat transfer conditions. The maximum heating temperature for 1 mm samples in a horizontal position in the natural heat-transfer conditions is reached within 20 – 25 min and is determined by the specific heat-releasing power of the conducting coating (Fig. 1).

For the same specific power of current-conducting coatings, the heating rate to a great extent depends on the substrate thickness, i.e., on the weight of the metal heated (Fig. 2). Thus, with the power of the samples equal to 1 kW (specific power 4.0 W/cm^2), the surface of a thin sheet sample (1 mm) is heated to 150°C in 50 – 55 sec, and a sample 15 mm thick under similar conditions is heated to 150°C during 8 – 9 min. The experiments indicate that the surface of samples on a 1-mm-thick substrate thickness of 1 mm becomes heated from room temperature to 150°C in 1.5 – 2 min with the specific heat-release power of the conducting coating equal to 2.5 W/cm^2.

The heater elements with the described conducting coatings were tested on electric radiator panels, whose efficiency was determined based on service testing for 10,000 h (the temperature on the panel amounted to 120 ± 5°C). The variation in the resistance of the coatings during the tests amounted to 2.2 – 2.3%.

Parameters of heater element formed on electric radiator panels

Electric resistance, Ω	194 ± 5
Specific surface resistance of coating, Ω/cm^2	5
Power, W.	250
Working voltage, V	220
Working temperature, °C	120 ± 5
Temperature coefficient of resistance in the temperature interval of 20 – 200°C, % · K^{-1}	0.102
Service life, h	> 10,000

Electric radiators were assembled from the obtained panels. The electric strength of the enameled insulation of the radiators was tested by applying a voltage of 1250 V (50 Hz) for 1 min between the conducting coating and the accessible metal parts (at room temperature).The glass enamel insulation consisting of one prime coat and two cover layers of enamel 12p of total thickness of 0.4 – 0.5 mm withstood the high-voltage test without breakdown. The resistance of the insulation measured between the conducting coating and the metal substrate at room temperature is equal to $10^8 – 10^9$ Ω.

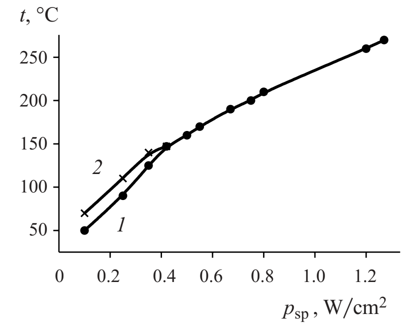

Fig. 1. Dependence of the temperature t of flat samples of size 150 × 250 mm (*1*) and a panel of size 468 × 496 mm (*2*) on the specific power p_{sp} of heater films.

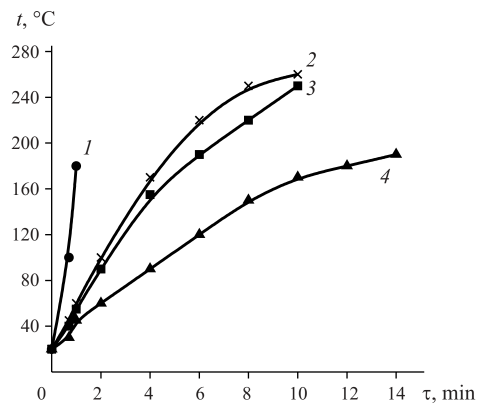

Fig. 2. Heating dynamics of the surface of electric heaters of power 1 kW, size 150 × 250 mm, and substrate thickness 1 (*1*), 5 (*2*), 8 (*3*), and 15 mm (*4*).

After exposure for 20 days in a chamber with 98% humidity and 40°C temperature, the coating resistance increases by 2.0 – 3.5%. The increase in resistance after 15 cycles of freezing to – 60°C and subsequent electric heating to 200°C is equal to less than 2.6%. The high stability of the conducting coating with respect to external atmospheric effects makes it possible to use it without additional sealing.

The developed conducting coating formed at low temperatures (560 – 580°C) has good service parameters and can be in radiators intended for heating of residential premises, railroad cars, etc., instead of the known oil radiators, which makes it possible to significantly simplify the design of the heaters.